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# INDUSTRIAL ILLEGAL TOXIC WASTE DISPOSAL VIA SMART DETECTION SYSTEM

**MUHAMMAD IZUAN BIN ABDULLAH**

**A thesis submitted in fulfilment of the**
**requirements for the award of the degree**
**of Bachelor in Electrical Engineering**
**(Control & Instrumentation)**

**Faculty of Electrical Engineering**
**Universiti Teknologi Malaysia**

**JULY 2012**

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*Dedicated to my beloved mom and dad,*

*Basariah binti Abdullah Sani and Abdullah bin Mohd Shahrani,*

*and both my sisters.*

*A special thanks for all your support, encouragement and understandings.*

*Thank you for everything*

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***'In The Name of ALLAH, The Most Gracious and The Most Merciful'***

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# ABSTRACT

In pursuing the goal of becoming a fully developed nation by the year 2020, pollution are among the main problems that still haunt the country. Water pollution in particular has occurred mainly due to the irresponsibility action of the industries that dispose the toxic and hazardous waste into the river. To prevent this action from happening, this project was created to detect any attempt from the industries to dispose their generated toxic or hazardous waste from the septic tank to the river. Built using an electrochemical gas sensor to detect the toxic being dispose, it will sense the toxic gas and send the address location of the industry who commit the offense to the authorities for further action. The system used GSM technology that integrated with a microcontroller to send and receive data wirelessly. A GSM Modem is used to send the address location of the industry via Short Messaging Service (SMS) whenever a toxic waste disposal is detected while a GSM phone is used to receive the SMS. Visual Basic programming is used to develop the GUI for the system in purpose to display the data received at the monitoring location. Through this project, a reliable and effective system is achieved to prevent the illegal toxic waste disposal by the industries.

# ABSTRAK

Dalam usaha untuk mencapai matlamat menjadi sebuah negara maju sepenuhnya menjelang tahun 2020, pencemaran adalah antara masalah utama yang masih menghantui negara. Pencemaran air khususnya telah berlaku disebabkan oleh tindakan tidak bertanggungjawab industri yang melupuskan sisa toksik dan berbahaya ke dalam sungai. Bagi menghalang tindakan ini daripada berlaku, projek ini telah diwujudkan untuk mengesan mana-mana percubaan dari industri untuk melupuskan sisa toksik atau berbahaya yang dihasilkan dari tangki septik ke sungai. Dibina dengan menggunakan sensor gas elektrokimia untuk mengesan sisa toksik yang dilupuskan, ia akan mengesan gas toksik dan menghantar alamat lokasi industri yang melakukan kesalahan itu kepada pihak berkuasa untuk tindakan selanjutnya. Sistem ini menggunakan teknologi GSM yang disepadukan dengan mikropengawal untuk menghantar dan menerima data tanpa wayar. Modem GSM digunakan untuk menghantar lokasi alamat industri melalui Khidmat Pesanan Ringkas (SMS) apabila pembuangan sisa toksik dikesan manakala telefon GSM digunakan untuk menerima SMS. Pengaturcaraan Visual Basic digunakan untuk membangunkan GUI bagi sistem bertujuan untuk memaparkan data yang diterima di lokasi pemantauan. Melalui projek ini, satu sistem yang boleh dipercayai dan berkesan dapat dicapai bagi mencegah pembuangan sisa toksik haram oleh industri.

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## LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| 3G | - | Third Generation |
| A/D | - | Analog to Digital |
| AC | - | Alternate Current |
| ADC | - | Analog to Digital Conversion |
| AT | - | Attention |
| CO | - | Carbon Monoxide |
| COM | - | Communication Port |
| CPU | - | Central Processing Unit |
| DC | - | Direct Current |
| DLL | - | Dynamic-Link-Library |
| DOE | - | Department of Environment |
| EEPROM | - | Electrically Erasable Programmable Read Only Memory |
| EQA | - | Environmental Quality Act |
| EXE | - | Running Executable Program |
| FYP1 | - | Final Year Project 1 |
| FYP2 | - | Final Year Project 2 |
| GDP | - | Gross Domestic Product |
| GPRS | - | Global Packet Radio Service |
| GPS | - | Global Positioning System |
| GSM | - | Global System for Mobile Communication |
| GUI | - | Graphical User Interface |
| HEX | - | Hexadecimal |
| I/O | - | Input Output |
| IC | - | Integrated Circuit |

| | | |
|---|---|---|
| ICSP | - | In-Circuit Serial Programming |
| ID | - | Identification |
| LCD | - | Liquid Crystal Display |
| LED | - | Light Emitting Diode |
| M2M | - | Machine-to-Machine |
| MCU | - | Microcontroller |
| MHz | - | Mega Hertz |
| OOP | - | Object Oriented Programming |
| PDU | - | Protocol Data Unit |
| PIC | - | Peripherals Interface Controller |
| PIN | - | Personal Identification Number |
| ppm | - | Part Per Million |
| RAM | - | Random Access Memory |
| RFID | - | Radio Frequency Identification |
| RL | - | Load Resistor |
| ROM | - | Read Only Memory |
| SIM | - | Subscriber Identity Module |
| SMS | - | Short Message Service |
| UART | - | Universal Asynchronous Receiver/Transmitter |
| UCS2 | - | 2-byte Universal Character Set |
| USB | - | Universal Serial Bus |
| V | - | Volt |
| VC | - | Circuit Voltage |
| VH | - | Heater Voltage |
| WAP | - | Wireless Application Protocol |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Malaysia has achieved remarkable success in various sectors of development especially in the manufacturing sector which experiencing tremendous rapid proliferation. The nation economic growth spurred by the development of manufacturing industries, proving that this sectors plays an important role in ensuring that the nation economy is thriving constantly. In 2011, it is reported by the Ministry of Finance that the manufacturing sector contributed RM 164.107 million to Malaysia's Gross Domestic Product (GDP), accounting for 27.92% of overall GDP in 2011, with 6.7% growth over the previous year [2]. Due to this rapid industrialisation, generation of toxic and hazardous waste have increased over the years.

Over the years, Environmental Quality Act 1974 is an act which is used to control most of the hazardous waste in Malaysia. Hazardous waste is subject to some type of recovery (recycling) operation, burned in integrated waste management centre incinerator, burned at local off-site clinical waste incinerators, transported to off-site disposal facilities or disposed for onsite treatment [1]. Out of 77 waste codes

listed on the Environmental Quality (Scheduled Waste) Regulations 2005, only 15 waste codes are allowed to be sent to the waste recyclers [1].

The incidence of illegal dumping by the industries is due to the highly expensive price of legal scheduled waste treatment. The waste generators have to pay more to dispose their waste compare to recycle. This has caused the river to be polluted by the industrial waste especially by toxic and hazardous waste. It was reported that there is an average of 97 cases of illegal toxic waste disposals from year 2001 to 2006 [3]. Furthermore, only 40 cases of illegal hazardous waste dumping have been successfully brought to court under Section 34(B) EQA 1974 and the rest of the culprits were not traced [3].

Therefore this project is design to effectively detect the toxic and hazardous waste that being disposed illegally by the industries to the river. A smart wireless system is used using GSM as the transmitter and the receiver to send and receive data from the detected location to the monitoring location. No matter where the location of the toxic waste being disposes, the authorities will always be notified by the system. Further action can be able to be taken on the party responsible and eventually preventing water pollution from happening.

## 1.2 Problem Statement

The problem of illegal dumping of toxic waste into the river by the industry is nothing new to the public. This problem often occurs, especially when it rains or rainy season. The industry will open up the toxic storage tank to dispose the toxic waste into the river.

This toxic waste will be channelled through the drain and eventually down into the nearby river. The strong river currents due to the rain will carry away the toxic waste being dumped. This results in the industry to escapes from any legal action because there is no evidence to show that they the one who dispose the toxic and hazardous waste into the river.

An effective and reliable wireless system is needed to detect the illegal disposal of toxic waste into the river by the industries. The system should be able to report the exact location of the incident to the authorities as soon as the toxic being dumped.

## 1.3 Objectives

The objectives of this project are as follows:

1. To reinforce capacities to detect and halt any illegal attempt by the industries to introduce toxic and hazardous substances into the river.
2. To meet the goals of eco-friendly development.
3. To avoid environmental pollution and adverse health effects due to the improper disposal by industries.

## 1.4 Scope of Project

To ensure that every objective outlined in the project can be implemented successfully, two types of scopes have been emphasized. Distribution of the two

scopes of this project is formulated to design of hardware and software design. For hardware, it can be categorized into three systems, namely:

1. PIC 16F877A Microcontroller
2. The sensing system
3. The wireless system

The system consists of an electrochemical gas sensor. It is used to detect the presence of toxic gas from the toxic waste being disposed while the wireless system consists of GSM Modem and a mobile phone to transmit and receive data.

There are two parts that require software design:
1. Microcontroller (PIC16F877A) Programming.
2. Monitoring System

MicroC PRO and PICkit 2 is used to write the c programming and program it into the PIC16F877A respectively while Visual Basic 2008 is used to create GUI application for the monitoring system.

## 1.5 Project Planning

The project is being done throughout two semester period continuously. Table 1.1 show the detail of works for the project that has been implemented in the first semester. During first semester, most of the works involve studying the microcontroller used for the project and learning the programming language. It also involved the designing of the wireless system hardware and identifying the component that need to be used for the project. Meanwhile, Table 1.2 shows the

works done during the second semester. The second semester is spent to complete the whole project including the programming and the hardware completion. Testing and analysis of the completed system are also conducted in the second semester before thesis writing is done.

**Table 1.1**: FYP1 Gantt chart

| No. | Task/Activities | September | | | October | | | | November | | | | December | | | | January | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 1. | FYP1 Briefing | | | | | | | | | | | | | | | | | | |
| 2. | Literature Review | | | | | | | | | | | | | | | | | | |
| 3. | Finding Suitable Sensor | | | | | | | | | | | | | | | | | | |
| 4. | Design of Suitable Wireless System | | | | | | | | | | | | | | | | | | |
| 5. | Prepare Project Proposal | | | | | | | | | | | | | | | | | | |
| 6. | Design Hardware | | | | | | | | | | | | | | | | | | |
| 7. | Completing Hardware | | | | | | | | | | | | | | | | | | |
| 8. | FYP1 Seminar & Report Preparation | | | | | | | | | | | | | | | | | | |

**Table 1.2**: FYP2 Gantt chart

| No. | Task/Activities | February | | March | | | | April | | | | May | | | | June | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 1. | Literature Review | | | | | | | | | | | | | | | | |
| 2. | Completing Hardware | | | | | | | | | | | | | | | | |
| 3. | Completing Program | | | | | | | | | | | | | | | | |
| 4. | System Testing and Analysis | | | | | | | | | | | | | | | | |
| 5. | System Implementation | | | | | | | | | | | | | | | | |
| 6. | Thesis Writing | | | | | | | | | | | | | | | | |
| 7. | FYP2 Seminar | | | | | | | | | | | | | | | | |

## 1.6 Methodology

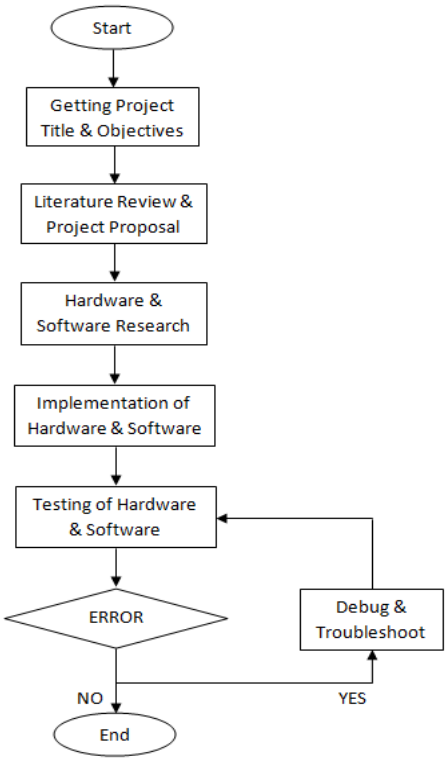


**Figure 1.1**: Flowchart of the project

The first method for the project development is getting the project title and objectives. After knowing about what project to develop for the final year project, the first thing that needs to be done is to find the most suitable title for the project. A good title can give a good impression on the project to be developed as a whole. Then the objectives of the project were found to increase the chances of leading to a specific outcome.

The next step is conducting literature review and writing the project proposal. All the information needed to complete the project is gathered and study by reviewing all journals, articles, books and previous research that related to this project. The internet also is used as one of the sources to find the most suitable wireless system that can be implemented in the project. After taking into account all

the factors that lead to the success of this project, GSM is selected as the most suitable system. The project proposal was later prepared in preparation for the beginning of the project.

Hardware research is done next to increase the understanding of every component, tools and instruments that will be used for the project including the sensor, PIC microcontroller and wireless GSM Modem. On this part, the proposed system is design, reviewed and understood more deeply in order to facilitate the future installation work. Software research is also similarly done to increase the understanding and avoid many mistakes during the programming process.

On the implementation of hardware and software part, after purchasing all the components for the project, the project development will preceded by installing the hardware according to the designed system. All the software will also be implemented to control the system and to create the project GUI eventually to complete the project.

The most important stage to ensure the success of the project is the final methodology which testing of hardware and software. The system will be tested on its effectiveness and any hardware or software errors will be repaired and improved to enable the project worked as well as it has been proposed. After completing all the processes, the project is ready and prepared to be use in the detecting of illegal toxic waste disposal by the industries.

## 1.7 Thesis Outline

This thesis consists of five chapters. Chapter 1 covers the project background, problem statements, objectives, project scope, project planning and methodology. Information collected throughout the two semesters for the project from literature review is written out in chapter 2. Chapter 3 explains the development of the project system. The project system combines the software and hardware of the entire project. Then, chapter 4 will concern about the result obtain from the test conducted and discussions of the analysis while the project conclusions and recommendation will wrap up in the final chapter.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Literature Background

Literature review was carried out throughout the whole project to gain knowledge and skills needed to complete this project. The main sources for this project are the previous project and research thesis that is related to the project and the other sources are books, journals and articles obtained from the internet. So this chapter discusses the projects and thesis related to this project.

By reviewing the previous works, research and projects, there are some ways and features that can be applied and added to ensure the project success. Theories and the knowledge related also are the important matter needed to develop this project. It has been acquired and carried out to achieve the objectives of this project. Thus the books, journals and articles are the most accurate source for it.

## 2.2 Toxic Waste

According to the definition outlined by the Occupational Safety and Health Act 1994, toxic intended as substances and preparations which if inhaled or digested, or penetrate the skin can cause serious health risks or death if it is ingested or enter the respiratory tract and skin contact with humans. Toxic is any waste in the form of liquids, solids or gases which may have adverse effects on human health, animals and the environment in general. Toxic levels of a substance to be determined by a laboratory test called the Toxicity Characteristic Leaching Procedure (TCLP).

Toxic materials contain carcinogens. This material may increase the chance of a person to get cancer. Toxic substances are released by industrial activities such as disposal of radioactive materials by nuclear plants, garbage from the residential areas, heavy metals from industrial plants and residues of herbicides or pesticides from agricultural activities.

## 2.3 Toxic and Hazardous Waste Management in Malaysia

The control of dangerous toxic and hazardous waste can be done comprehensively with the facilities and technologies provided. Malaysia uses a variety of ways of disposing or treat dangerous toxic waste that are generated such as the use of sanitary landfills, incinerators, physical and chemical treatment and stabilization. The process of toxic and hazardous waste management is shown in the Figure 2.1. All waste generated by industries will be classified before transportation process can be performed. Some of the toxic and hazardous waste will be delivered to recovery and treatment facility while the other half will be transported directly to the grave facilities for disposal.

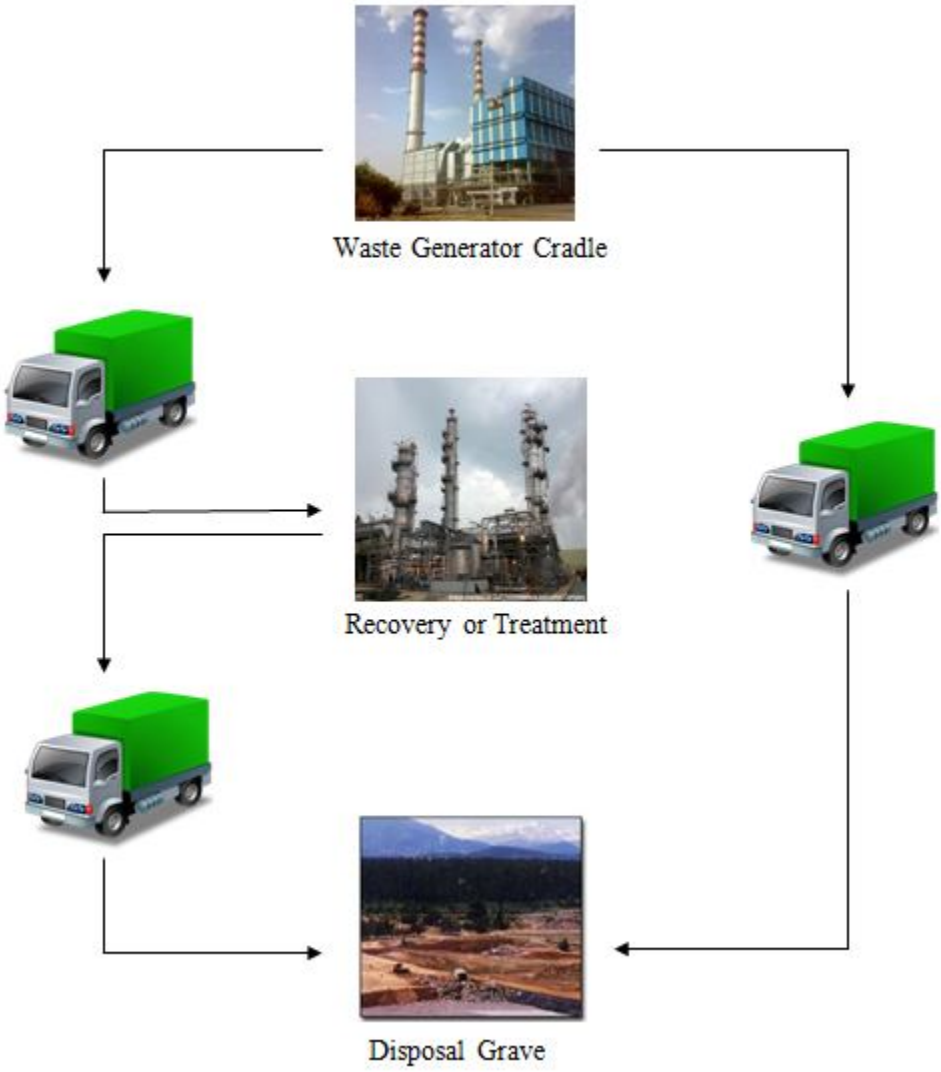


**Figure 2.1**: Toxic and Hazardous Waste Management Process

The largest center for the management of toxic and hazardous waste in Malaysia is the Integrated Hazardous Waste Treatment Plant located at Bukit Nanas Negeri Sembilan manages by Kualiti Alam. This center covers the entire process of waste management starting from collection of waste from generators, transportation, and treatment up to disposal. It has the facilities for high temperature incineration, physical and chemical treatment, stabilization and secure landfill. Most of the toxic and hazardous waste in Peninsular Malaysia are managed by this facility.

## 2.4 Cause of Water Pollution in Malaysia

Water pollution is a pollution that occurs in rivers, lakes and sea. The main sources of water pollution in Malaysia are such littering from residential areas along rivers, lakes and sea side. Water pollution can be categorized or arising from fixed sources and the not fixed (non point) source. The causes of fixed sources include sewage treatment plants, industrial manufacturing, agro-based industries and animals farms. The cause of not fixed (non point) is defined as the resources that are not derived from one discharge point.

In 2007, the Department of Environment (DOE) has recorded a total of 19320 causes of water pollution. They comprised of sewage treatment plant of 9337 (48.3%), including 640 network pumping stations, manufacturing industries 8708 (45.1%), animals farms and agriculture-based industries 779 (4.0%) and 485 (2.5%) respectively. Disposal of toxic waste along the river by factories also a source of water pollution in Malaysia. Toxic waste is discarded and passed into the drains, ditches, canals and into the river.

DOE has collected statistics on the causes of water pollution from the manufacturing and agro-based industries via on site excursions and questionnaires. The total amount of water pollution from both the industry is at 9204.

## 2.5 Current Technology used by Department of Environment

There are many technologies that can be used to enable detection of any activity contrary to the law that affects the environment, especially in the detection of illegal toxic waste disposal. The DOE in Malaysia has been using the E-Consignment Note system to observe the disposal of wastes so that it is being properly managed.

### 2.5.1 E-Consignment Note System

In order to ensure efficient and safe management of the scheduled wastes and to monitor the generation and disposal of toxic waste, Department of Environment uses E-Consignment Note system. DOE starts to enforce E-Consignment Note system beginning on January 2007 to insert the consignment note of the scheduled wastes information by using the email facility. All manufacturers of scheduled wastes, transport contractors and recipients of the scheduled wastes are required to use this system for every movement of the scheduled wastes.

E-Consignment Note shall provide reports generation of scheduled wastes through the web as prior notification to the DOE if there are any generation of scheduled wastes by the premises. Through this system, the DOE only required to obtain reports generation of scheduled wastes from E-Consignment web applications without having to go to the affected premises. DOE can identify any environmental problems that arise by a surprise visit to a particular premise identified to produce the scheduled wastes by making a comparison between the wastes declared and the wastes available at the premises.

## 2.6 Previous Related Projects

To ensure that this project solved the described problem statement, the previous projects have been used as references. The reason that the previous projects are referred to is to learn and improve all the advantages and disadvantages of all these projects. Any problems encountered by the previous projects will successfully avoided in trying to develop the current project.

### 2.6.1 Toxic Gas Release Alarm System Using PIC Microcontroller by ZARITH SOFIA SURAYA BT HJ BAKERI [5]

This project was created to solve the problem that occurred from the carbon monoxide gas released by motor vehicles and other gasoline powered tools, heaters, and cooking equipment that is dangerous to human health by detecting the gas using TGS 2442 gas sensor and generate an alarm signal when the detected gas reach its hazardous level. Powered by Microchip's PIC18F2550, this project enable users not only be alarmed when the carbon monoxide gas reach a dangerous level but also to be aware of the gas concentration level which will be displayed on the system's LCD. Built using a latest carbon monoxide sensor TGS 2442, the system can detect up to 1000 ppm of carbon monoxide level. The alarm signal system consists of LEDs, LCD and buzzer which will triggered according to the gas concentration level detected by the sensor.

This project limitation is that it's only detected carbon monoxide gas in residential area and signals the alarm system to the nearby people. The system also does not report the occurrence of dangerous volume of the toxic gas emission to the authorities for further action.

### 2.6.2 Smart Management Parking System by MOHD FANDY BIN YA RAHIM [6]

This project is about the management of parking system services. Smart management parking system is developed to optimize the parking system so that it will be more users friendly. The objective of this system is to introduce the old system into the new system by upgrading new technologies. The new technologies are using reservation parking space and by knowing the information parking space available. The technologies that will be use in this project are the Short Message Service (SMS) system integrated with the new microcontroller. The project also include the GUI technologies develop by using the Visual Basic 6.0 to control the system of the project in the control room.

This project is using GSM technology to communicate between user and the control room. The GSM technology can be implemented in the industrial illegal toxic waste disposal via smart detection system project for wireless communication. The technology is modified so that the data will automatically be send through a GSM Modem and receive by a mobile phone act as a modem that will be represented on the monitoring system.

### 2.6.3 Smart Communication Using Radio Frequency Identification and GPRS Modem by MOHAMAD SAIFUL ISLAM BIN AZIZ [7]

This project presented about teachers and parents wireless communication using Global Packet Radio Service (GPRS) Modem and Radio Frequency Identification (RFID) when there is an emergency appears towards their children in school. The purpose of this project is to invent a cost effective communication system by using RFID technology and GPRS. This project consists of 125 kHz

passive RFID/ID tag that will read by RFID reader and GPRS modem send a SMS message to parents. Both RFID reader and also GPRS modem will be controlled by microcontroller that acts as a 'brain' for the whole system. Parents will receive a SMS message about the situation of their children at pre-school as the passive RFID/ID tag has been read by RFID reader.

The wireless communication of this project is studied and then implemented to the development of industrial illegal toxic waste disposal via smart detection system project. The way RFID triggered the GSM to send SMS is slightly replicate in gas sensor and GSM interface of this project.

## 2.7 Summary of Previous Related Projects

Each of the previous projects related to the projects to be developed are reviewed and taken into consideration. All of these projects have it own advantages and disadvantages that can be highlighted to the use of Illegal Industrial Toxic Waste Disposal via Smart Detection System. Although previous projects have different objectives, every project is viewed in terms of technology used. For example, gas detection project using gas sensor. A similar technology is used to detect toxic waste for the projects to be developed, but with different applications.

GSM technology used by the previous project also learned and considered carefully so that it can be applied more effectively in ensuring that illegal dumping of toxic waste can be reported to the relevant authorities. Display method used by one of the previous projects also applied with a more convenient and simple approach to establish a user friendly advantage for the project to be developed.

## 2.8 Short Message Service (SMS)

Short Message Service (SMS) is a communications service that uses standardized communication protocol. It allows the exchange of text messages which involves one mobile phone to another mobile phone. With an estimated of 2.4 billion active users using SMS services via their mobile phones, SMS is an application data that most widely used in the world. SMS technology used today has greatly assisted in the advancement and the growth of communication systems in the world.

SMS in the first place is designed as part of the GSM, but is currently available on various networks, including 3G networks. However, not all text messaging systems use SMS. An SMS consist a maximum of 140 bytes (1120 bits) of data that is 160 characters when the 7-bit character encoding is used. The 7-bit characters are suitable for encoding Latin characters like English letters. Furthermore, one SMS may also include up to 70 characters if 16-bit Unicode UCS2 character encoding is used. Almost all wireless carriers provide a cheap SMS message services. Unlike SMS, not all mobile phone models provide mobile technologies such as WAP and Java.

## 2.9 Electrochemical Gas Sensor

The electrochemical sensors have been widely used in the chemical and biomedical sensing element as a whole or part. Electrochemical sensor can generally be split into the conductivity/capacitance, potentiometric, amperometric and voltammetric sensors. The amperometric and voltammetric sensors are characterized by their current-potential relationship with the electrochemical system and are less well-defined. Amperometric sensors can also be viewed as a subclass of voltammetric sensors.

Electrochemical sensor used an arrangement of two or three electrochemical cell. For the purposes of measurement, the electrochemical sensors may be made in steady state or transient. To increase the sensor selectivity and sensitivity, the mode of operation determined will be adjusted. This will cause the current or potential for the electrochemical sensor will show various values.

## 2.10 AT Command

AT command is the command uses to control the GSM modem or mobile phone to perform task for example SMS sending or phone calling. Dial modems, mobile phones and GSM modems support a common set of AT commands standard. AT commands is developed from Hayes command set which is function as a based messages exchanged between applications in order to manage GSM related events or services. AT command works as a language for GSM modem to schedule a command, a script, or a program to run at a specified date and time and as command to view existing scheduled tasks. The main application for the extended AT commands are to managing SMS transmission, monitoring the signal strength and view phone book entries.

Extended AT commands allow us to:

1. Reading, writing and deleting SMS messages.
2. Sending SMS messages.
3. Monitoring the signal strength.
4. Monitoring the charging status and charge level of the battery.
5. Reading, writing and searching phone book entries.

**Table 2.1:** Example of AT Command

| | |
|---|---|
| **AT+CGMI** | Manufacture Identification |
| **AT+CGMM** | Request model identification |
| **AT+CGMR** | Request revision identification |
| **AT+CGSN** | Product serial number |
| **ATD** | Dial command |
| **ATH** | Hang-Up command |
| **AT+CMGF** | Preferred message format |
| **AT+CMGS** | Send message |

The AT command can be write and tested through the hyperterminal. Before the writing of AT command, the mobile has to be test in order to determine which type of SMS mode it is supporting. The SMS mode is divided into 2 types, one is called PDU mode and another is called text mode. For PDU mode, the message content that wish to send has to be converted to HEX code before sending process is made. For text mode, SMS can simply be the alphabet format that is written normally. There are also mobile phones that support type of SMS mode. Therefore it's easier if mobile phone that supports both modes is used

## 2.11 Microsoft Visual Basic 2008

Roughly there are hundreds of programming languages adopted by programmers today, either amateur or professional. Every language is applied to solve all sorts of problems. Language which is considered as procedures such as BASIC, C, COBOL, FORTRAN, and Pascal can be classified as original or traditional language. It is the language of procedures because the program that determines the correct sequence for all operations. Further instructions for

implementation will be determined by the program logic in respond to condition and user demand.

C++, C# and Visual BASIC is a new programming languages using two different approaches such as object oriented (OOP) and event-driven programming. Microsoft Visual Basic refers to event-driven a programming language that has many elements of object-oriented language like Java. In an event-driven model the program is not in accordance with a logical sequence. The sequence of execution do not need be controlled and determined in this case.

In accordance with the transition of the world to graphical user interface (GUI), Visual Basic is one of the languages that led to the transition. Visual Basic was designed to enable programs to be carried out under windows without any complexity generally associated with the programming window. Designed screen can held standard window buttons such as command buttons, check boxes, selection buttons, text boxes, and so forth. Every object of this window operates as predicted, resulting in a window "standard" user interface.

# CHAPTER 3

# DEVELOPMENT OF SYSTEM

## 3.1 Hardware Development

### 3.1.1 PIC Microcontroller 16F877A

PIC is referred to “Peripherals Interface Controller”. 16F877A microcontroller has been selected for the development of the project. The PIC was chosen based on functions required for the system usage. The IC chip having internal-built-in ADC (Analog to Digital Conversion) and UART function. Gas sensor used in this project produced output in analog values. Therefore, function of the ADC must be adopted for the conversion from analog values to digital values due to the nature of the microcontroller that can only receive digital value, either 1 or 0.

It utilizes two types of memories which are program memory and data memory as internal memories. A share of 14.3 Kbytes (8192 words) consisting of flash memory, and memory data contained in the program memory. Data memory has two sources of data memory which 368-byte RAM (random access memory) and 256-byte EEPROM (electrical erasable programmable ROM).

The core feature includes interrupt capability up to 14 sources, power saving sleep mode, and single 5V In-Circuit Serial Programming (ICSP) capability. The sink/source current, which indicates a driving power from I/O port, is high with 25mA. Power consumption is less than 2mA in 5V operating condition. All the individual characteristics contained in the IC make it suitable to be applied into diverse types of systems such as industrial, automotive, hardware and consumer application system.

In addition, only 35 instructions are needed to know by the user makes this PIC16F877A microcontroller a user-friendly IC. These instructions are easy to learn because all instructions are in single cycle except for the branch command and the interrupt command. The interface between the GSM modem and the gas sensor can also be done handier because PIC16F877A also has I/O pins of 33 that make it easier to be applied in this project.

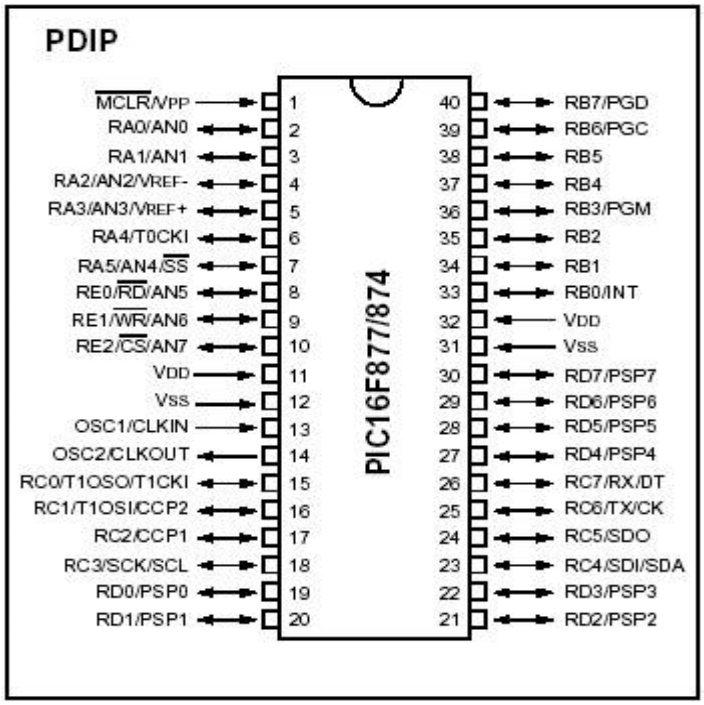


**Figure 3.1**: PIC 16F877A pin diagram

### 3.1.2 Figaro TGS 2600 Electrochemical Gas Sensor

Electrochemical gas sensors are the largest group of chemical sensors, representing approximately 58% of the total. Electrochemical gas sensors have been used extensively either as a whole or an integral part of a chemical and biomedical sensing element. Electrochemical sensors are commonly used especially to detect oxygen and toxic gases in the environment. Each of the sensors is specially designed to only detect the gas that need to be detected.

This project uses Figaro TGS 2600 electrochemical gas sensor for the detection of toxic waste which is on this case produces carbon monoxide gases for the project development. This sensor has high sensitivity to a variety of air contaminants gas, particularly to low concentrations gas contaminants such as hydrogen and carbon monoxide (CO). Carbon monoxide is a gas that is colourless and odourless which is produced by all internal combustion engines including diesel. It is also produced from the burning of wood, paper or plastic products. The sensor can also detect hydrogen at a few ppm levels. Compared with other sensors, TGS 2600 have a longer useful life and less costly. Figure 3.2 shows the Figaro TGS 2600 gas sensor

**Figure 3.2**: Figaro TGS 2600 Gas Sensor

Heater voltage (VH) and the circuit voltage (VC) are required by the sensor to function. To maintain the sensing element at a certain temperature, heater voltage

(VH) is required for the integrated heater. The measurement of output voltage (Vout) is performed across the load resistor (RL) connected in series with the sensor. This sensor has a polarity, so the DC voltage is required for the circuit voltage. The value of load resistance chosen for this project is 47k ohms. Figure 3.3 shows the circuit connection for gas sensor.

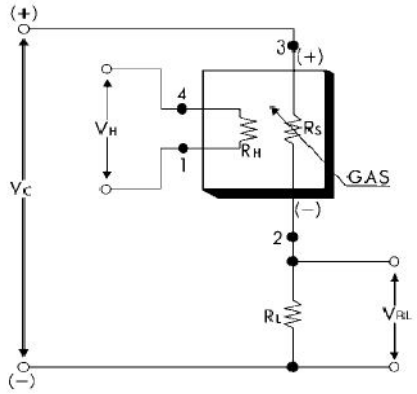


**Figure 3.3**: Gas Sensor Circuit Connection [12]

### 3.1.3 iTegno 3832 GSM Modem

GSM stands for Global System for Mobile communication. It is widely use as the globally accepted standard for digital cellular communication. Cell phones connect to it by searching for cells in the immediate vicinity. In order for GSM Modem to operate, it needs a Subscriber Identity Module (SIM) card from a wireless carrier. GSM modems convert digital data to Short Message Service (SMS) messages for sending and receiving messages over the wireless network.

There are many different type of GSM modem that can be use in the market today. In this project, the iTegno 3832 GSM modem is used as a transmitter for the wireless communication. It is specifically ideal for reliable communication over

GPRS and GSM for corporate and industrial usage and can be deployed in various Machine-to-Machine (M2M) applications.

This modem has many advantages that will benefit consumers, particularly in the industries. One of the advantages is that it has a wide selection of interface which is designed so that it can provide connectivity to any application of machine-to-machine (M2M). In this case, the project use RS232 interface to facilitate communication between the microcontroller and the modem. Another advantage of this modem is that it has an external antenna where this features can improve the sensitivity and flexibility for industrial aid application for installation in remote areas. [14] The modem is free from battery supply demand because power is supplied from external power source which is AC supply thus it maintains a process without interference with other power supply from other circuit and components. Figure 3.4 shows the standard package of iTegno 3832 modem.

**Figure 3.4**: Standard Package of iTegno 3832 Modem

### 3.1.4 Mobile Phone

The project uses GSM technology which is widely used in today mobile phones. Mobile phones work by connecting to a wireless communication network provided by mobile phone operators via radio waves or satellite transmissions. A mobile phone is needed as a receiver for the system connected to a computer to complement the wireless communication. A wide range of mobile phones can be applied to this project as long as the phone inbox message can be accessed. A Samsung Galaxy ACE is used as a GSM receiver to receive all the SMS sent to the monitoring location.

### 3.1.5 SK40C

SK40C was used in this project to simplify the overall system. It is designed as an easy-to-start solution for PIC MCU users. Users can install the I/O components using any suitable manner. This kit comes without the PIC microcontroller to give freedom for the user to select the PIC model required. SK40C also comes with the basic elements for the user initiating the development of a project. It offers features of plug and use. It also has ICSP programming port so that it can be directly connected to computer for PIC burning process without taking off the PIC from SK40C.[15]

The SK40C come with additional features:

- 2 x Programmable switch
- 2 x LED indicator
- 20MHz crystal oscillator

- UART communication
- USB on board.

Both switch connected to RB0 and RB1 on the SK40C are used in this project with include the RESET switch for resetting the system. The UART communication or Tx and Rx pin of SK40C that are connected to RC6 and RC7 respectively are also used for PIC and GSM communication. Figure 3.5 shows the SK40C.

**Figure 3.5**: PIC Starter Kit SK40C

### 3.1.6 16x2 Liquid Crystal Display (LCD)

Liquid crystal display shown in Figure 3.6 functions as the output of the microcontroller. It is used to display a word or number depending on project needs. Value of 2 for 2x16 means two lines that can be displayed (the word or number), while 16 denotes the number of data pins which is used to interface the microcontroller.

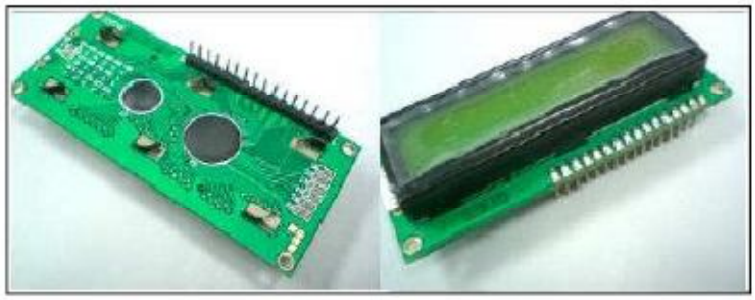

**Figure 3.6**: 16x2 LCD

For this project, LCD is connected to SK40C to display the percentage of output voltage when toxic waste is detected. It also shows the user the operating status of the system. The LCD uses low power and makes it easy for interface between the PIC microcontrollers. Figure 3.7 shows the connection between SK40C and LCD.

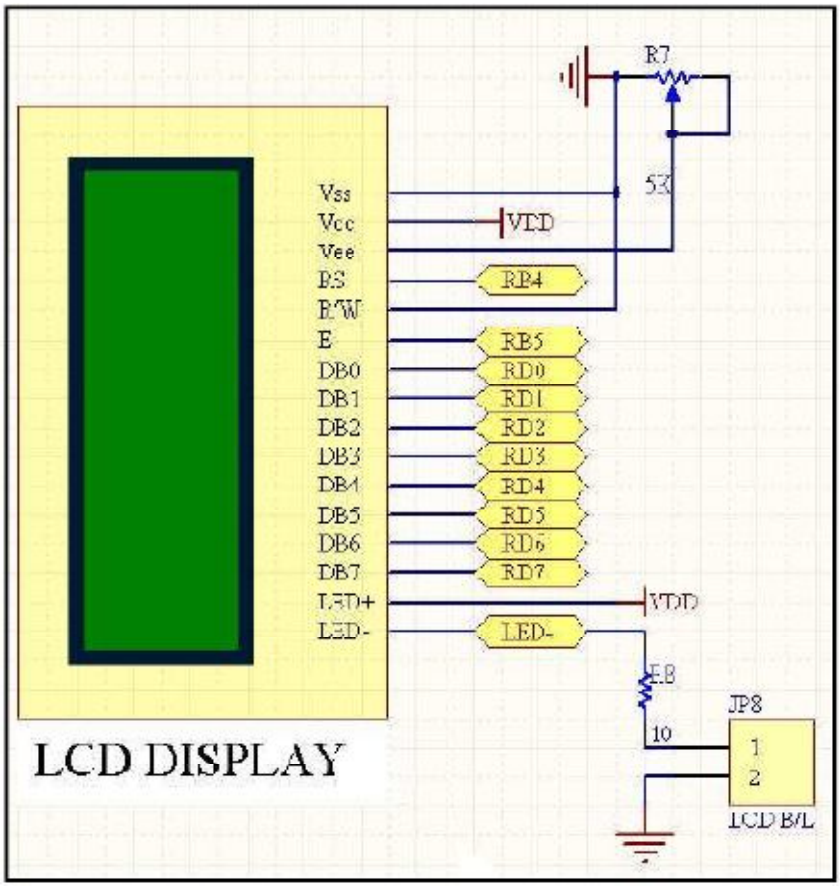


**Figure 3.7**: Schematic for LCD Connection

### 3.1.7 UART to RS232 Converter

PIC Microcontroller used UART signal while GSM Modem used RS232 signal. RS232 signal voltage is -15V to +15 V while the UART signal voltage is 0V to 5V. Logic high or '1' for RS232 is -15V to-3V, logic low or '0' for RS232 is 3V to 15V. Logic high or '1' for the UART is 2V to 5V while logic low or '0' for the UART is 0V to 0.8V. The difference signals used by the two devices caused it to be not applicable for a direct connection. To overcome this signal inequality, a UART to RS232 converter is used for this project.

The main component of the UART to Serial converter circuit is MAX232. MAX232 is the chip that is used to connect between RS232 and UART signals. MAX232 has a 16 pin and the input voltage is 5V. MAX232 has two sets of UART/RS232 converter. [16] Pin 11 and 10 are input UART or UART transmit, pins 14 and 7 are output RS232 or RS232 receive. Pin 12 and 9 is the output UART or UART receive, 13 and 8 pin RS232 or RS232 input is transmit. The schematic circuit for UART to RS232 converter and the actual circuit are shown in Figure 3.8 and Figure 3.9 respectively.

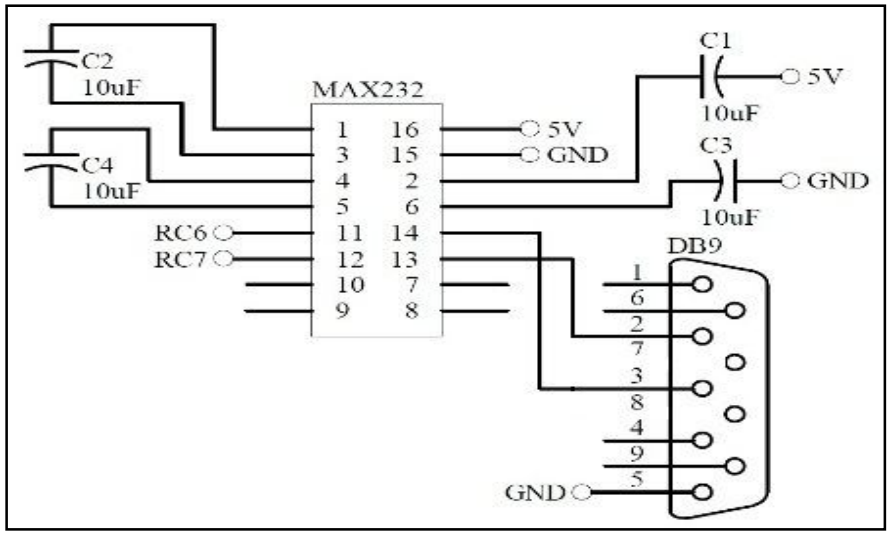


**Figure 3.8**: UART to RS232 Converter Schematic Diagram

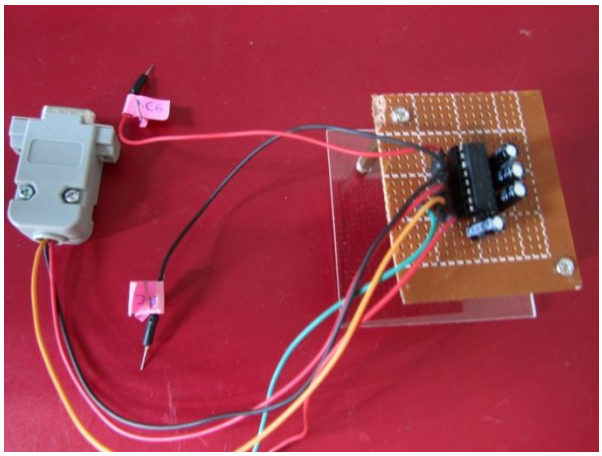

**Figure 3.9**: UART to RS232 Converter

## 3.2 Software Development

### 3.2.1 PIC Microcontroller Programming

There are two essential processes for the PIC microcontroller programming process which are to write a program and burn it into the microcontroller IC. After the PIC program is written and successfully compile, the program was burned into the microcontroller IC using the PICkit 2 software.

#### 3.2.1.1 MicroC Pro

MicroC is a low cost C language compiler for PIC MCUs. It is optimized for the limited and specialized environment for the embedded microcontrollers. Its

purpose is to provide the developer or programmer with the easiest ways to develop applications for embedded systems by providing the same performance or outcomes. MicroC is portable and was design to supports many CPU architecture. MicroC is supplied as a Developer's Kit with everything you need to develop for a C and assembly language software for a particular CPU. This software is used to create the system program in C language. Figure 3.10 shows the software interface of MicroC Pro.

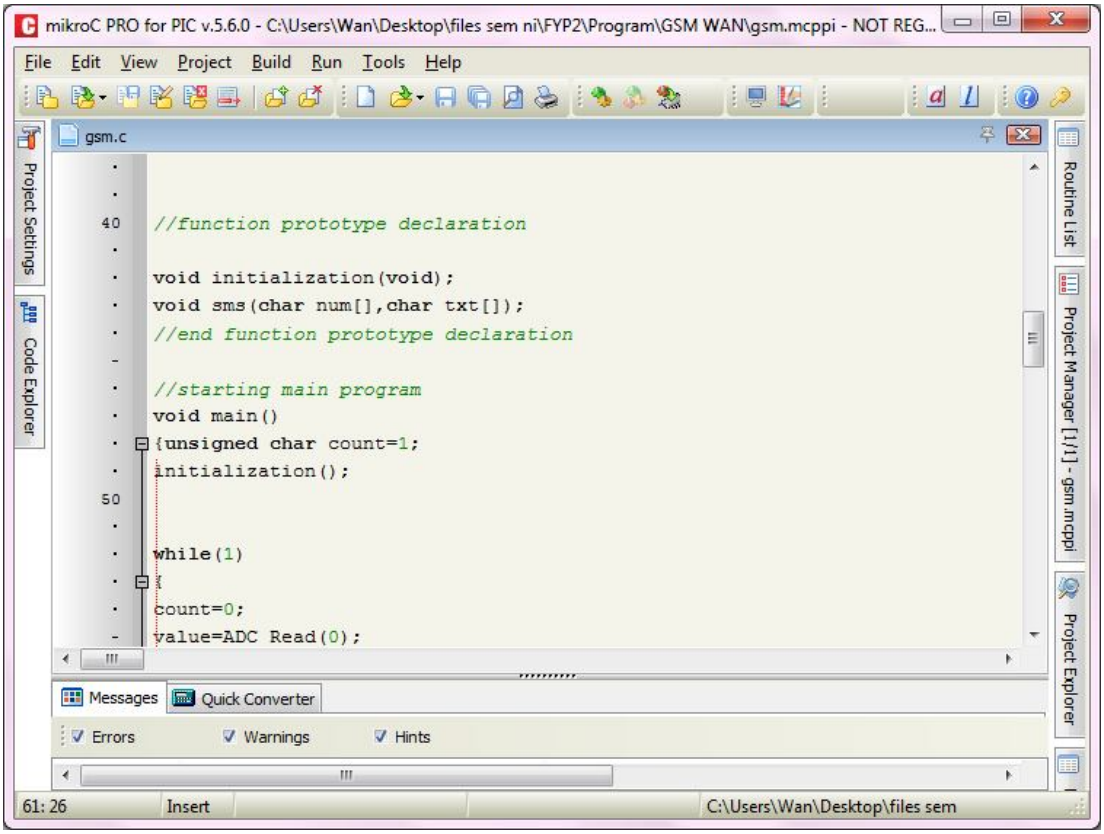


**Figure 3.10:** MicroC Pro Software Interface

### 3.2.1.2 PICkit 2

Microchip Technology created PICkit 2 as a programmer for PIC microcontrollers. PICkit 2 software is used to burn the hex file of the programming into the PIC 16F877A. It supports a maximum of 4M bytes of memory for programmer-to-go feature.

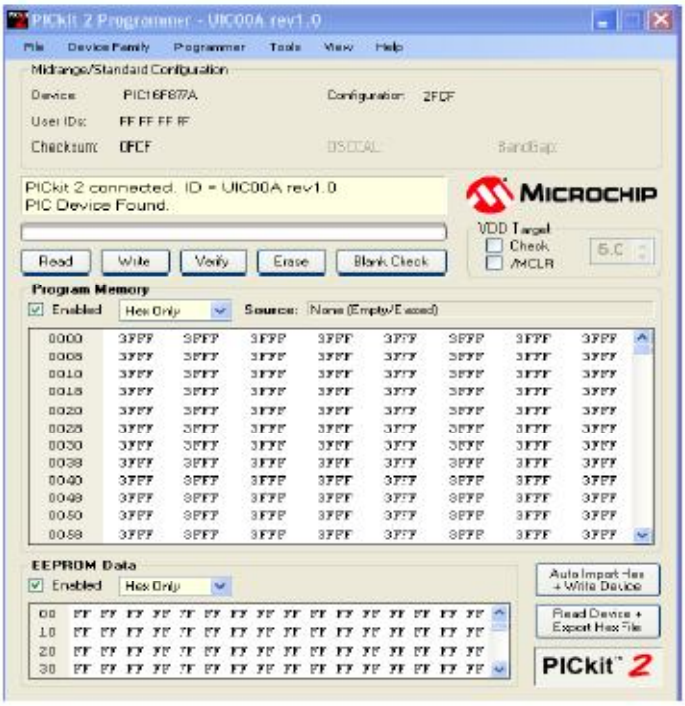


**Figure 3.11**: PICkit 2 Programmer Software

### 3.2.2 GUI Application Programming

In order to obtain a good result on the location of monitoring, GUI application is very important for the whole system for this project. This application was developed using Visual Basic 2008.

### 3.2.2.1 Microsoft Visual Basic 2008

Visual Basic is a very well known language in the commercial world. It is because it allows the programmer to develop a Windows-based program with a simple and rapid pace. Visual Basic programmer can add a large amount of code just by dragging and dropping controls, like the buttons and the dialog boxes, and later determine the appearance and behaviour. Each of these windows objects produces a standard user interface that makes the program becomes user friendly. This language not only enables programmers to develop simple GUI applications, but also complex applications.

Figure 3.12 shows the flowchart for the GUI application located at the monitoring location developed using Microsoft Visual Basic 2008. When the application is run, the user must select the correct communication (COM) port and baud rate of the connected mobile phone. The user can obtain this information by accessing the device manager of the computer.

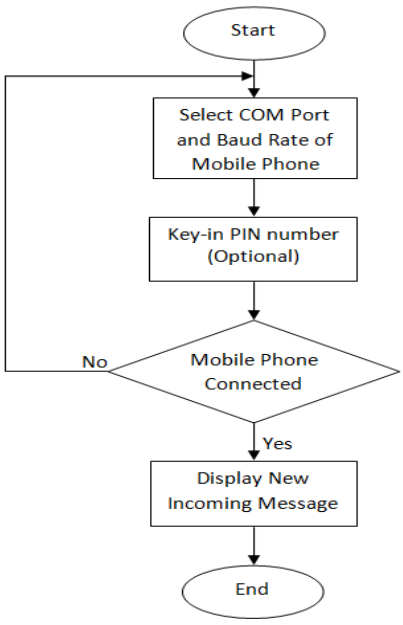


**Figure 3.12**: Flowchart of GUI Application

Every computer today is developed with a COM port or known as the serial port. It is an I/O port that is used by computers to produce asynchronous communication between serial devices or in this case a mobile phone and computers with the ability to send and receive data. Baud rate can be interpreted as transmission speed or rate of the number of symbols per second sent and received between two different communication channels. If a user accidentally selecting the wrong COM port for the mobile phones connected to the computer, a screen exactly like Figure 3.13 will be shown to the user.

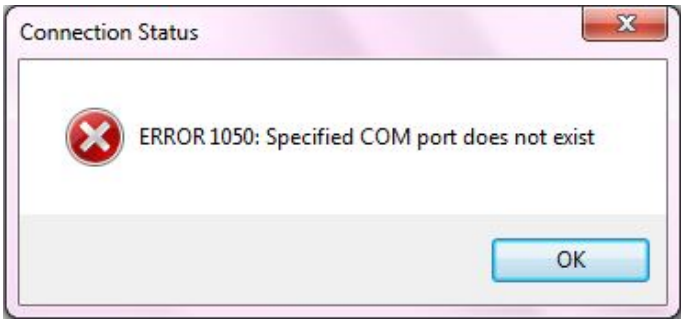


**Figure 3.13**: COM port error message box

For security reasons, the application also required the correct mobile phone PIN code before it can be applicable. If the PIN number is not inserted in the PIN box provided in the application, an error message is shown like in Figure 3.14.

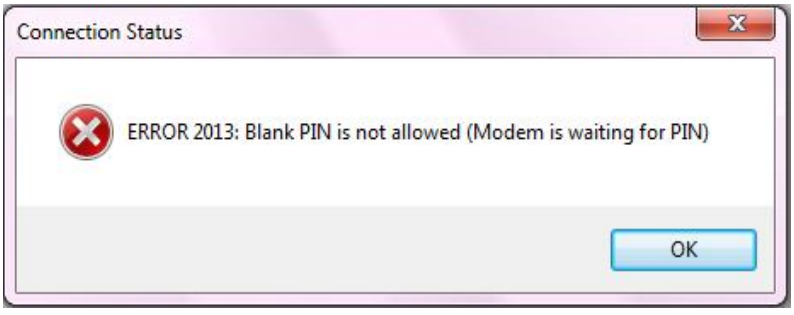


**Figure 3.14**: PIN error message box

After the three conditions are satisfied and the connect button is clicked, the application will show “Please Wait” at the connect button indicate that the computer and mobile phone communication is being processed as shown in Figure 3.15. Eventually the mobile phone will be connected successfully with the GUI application while connection will fail if contrary. A message box will appear as shown in Figure 3.16 when a successful connection has been made. Figure 3.17 shows the main form for the GUI application.

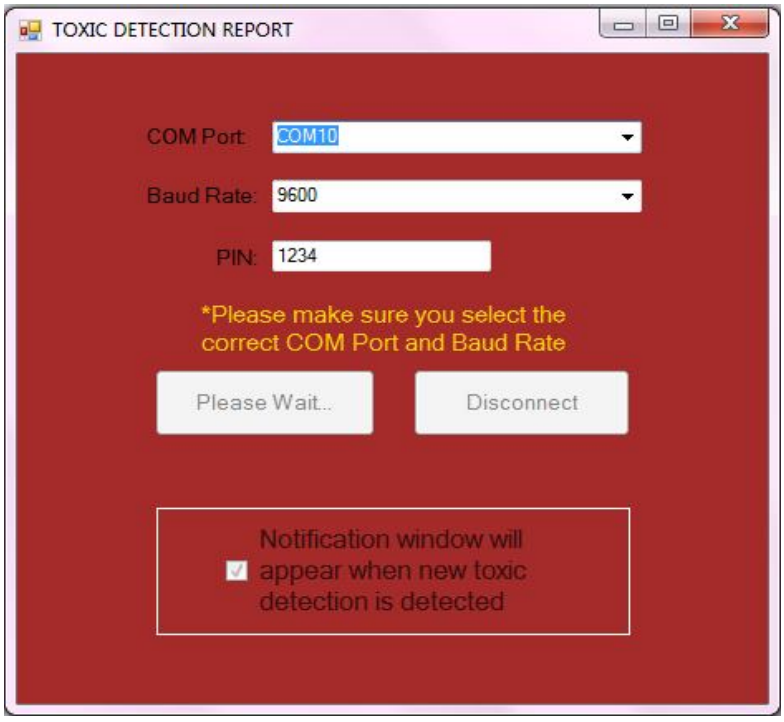


**Figure 3.15:** Please Wait sign at connect button

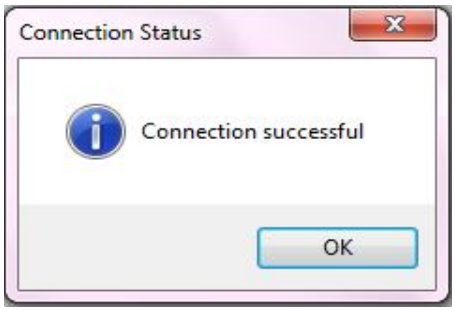


**Figure 3.16:** Successful Connection message box

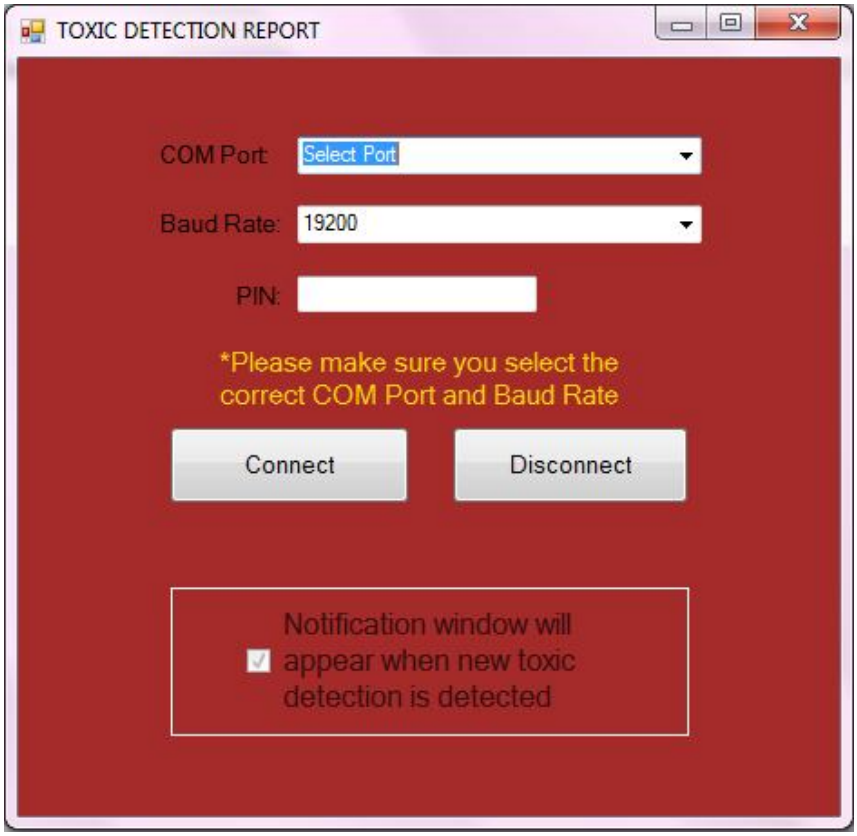


**Figure 3.17**: GUI Application Main Form

## 3.3 System Integration

In order to enable this project succeeded, the project is divided into the detection system and monitoring system. Integration between both systems especially the software and hardware integration is very important to enable the whole system to function properly. The monitoring system is the most crucial because it involves the hardware and software to integrate with each other for the system to work.

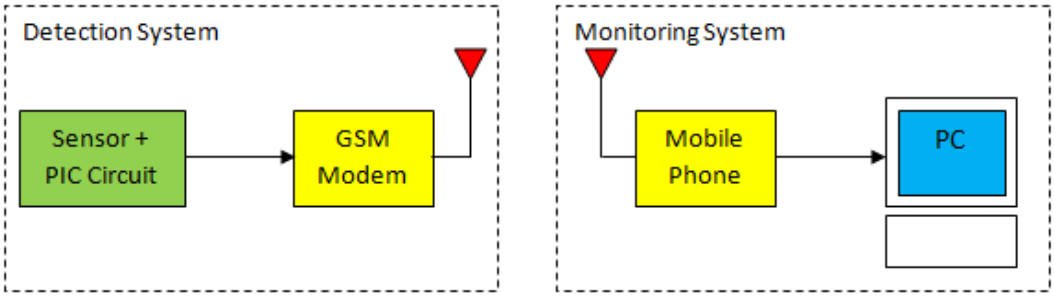


**Figure 3.18**: System Architecture

### 3.3.1 Mobile Phone with Visual Basic 2008

The monitoring system demand mobile phone with Visual Basic 2008 interface. This interface is performed by using a dynamic-link-library (DLL) that act as a reference for Visual Basic 2008. A dynamic-link-library (DLL) is a collection of small programs, which can be called upon when needed by the running executable program (EXE). The DLL lets the program to communicate with a specific device connected to the computer COM port to do a particular function. This project uses the mCoreLib.dll as reference file.

The mCoreLib.dll is an ActiveX SMS Component that will enable applications to send and receive SMS with robust and user friendly advantages. It can be used with any GSM modem or mobile phone connected to the computer COM port using a data cable. The mCoreLib.dll reference is add in Visual Basic 2008 as shown in Figure 3.19

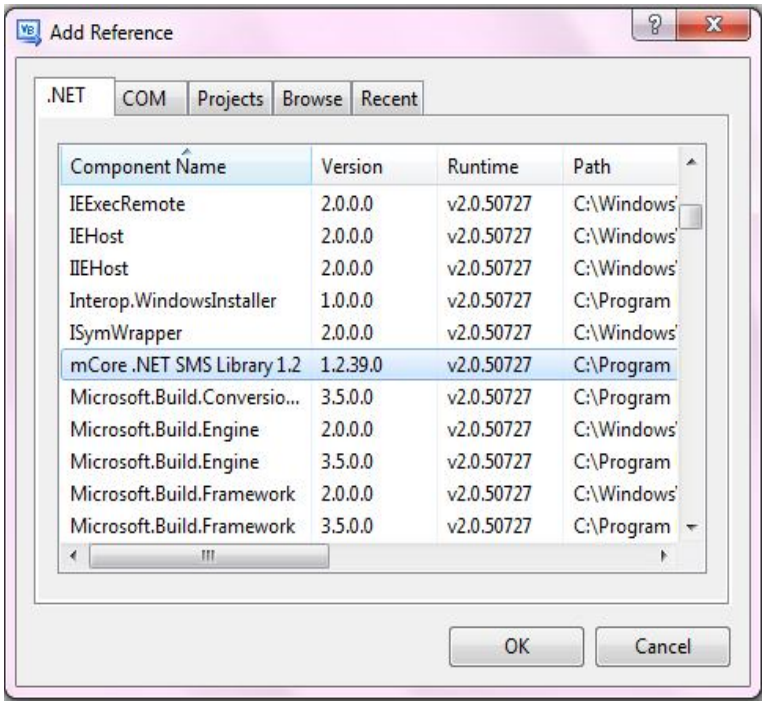


**Figure 3.19**: The mCoreLib.dll reference

Once the reference has been set up on the DLL file, the declaration must be defined. Figure 3.20 shown the functions are then similar to System.IO.Ports.SerialPort but the manufacturer replaced the name as mCoreSMS. The new message received is retrieved by using a special function by mCoreSMS and display in a message box. Figure 3.21 shows the function used to display the new incoming message. Functions e.Phone, e.TimeStampRFC and e.TextMessage displays the detection system phone number, date and time of report, and the factory address respectively.

```
Public Class frmMain
    Private WithEvents objSMS As New mCore.SMS
    Private strMyAppName As String = "Connection Status"
    Private blnFormLoaded As Boolean = False
```

**Figure 3.20**: The mCore.SMS library defined

```
My.Computer.Audio.Play(My.Resources.Siren_Wav___MP3_Sounds,AudioPlayMode.Background)
MsgBox("FROM: " & e.Phone & vbCrLf & vbCrLf & "DATE/TIME: " & e.TimeStampRFC & vbCrLf & vbCrLf &
"FACTORY ADDRESS" & vbCrLf & e.TextMessage, MsgBoxStyle.Information, "NEW MESSAGE RECEIVED...")
```

**Figure 3.21**: Function to read message from mobile phone

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1 Background of Result

This chapter will be discussing on the results obtain from this project starting from the detection system part which the electrochemical sensor and GSM modem to the monitoring system part where the computer and mobile phone interface result is discussed. All the result will be shown and the analysis will be discussed in detail.

## 4.2 System Flowchart

The system flowchart is shown by Figure 4.1. The system will be installed near the septic tank of the industry to make it easier to detect any disposal of the toxic waste by the industry. When the industry tries to dispose the hazardous and toxic waste to the river by channel it trough the drain, the electrochemical sensor will sense the gas that released from the disposed waste. The GSM Modem then will send the address location of the industry to another mobile phone. The mobile phone is

located at a monitoring system where the data collected will be displayed to the authority. The authority next will taking on the role by going to the industry location according to the address received by the system and take legal action against the industry that commit the offense. The system then will be reset by the authority to enable the system in normal condition.

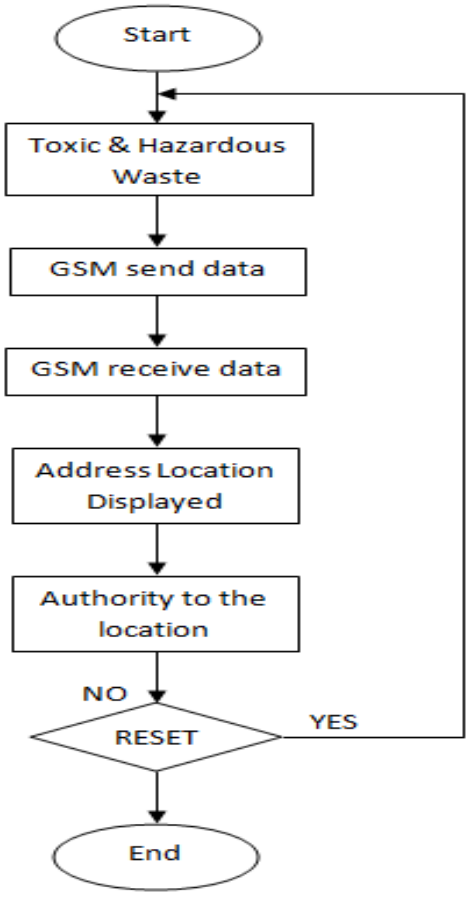


**Figure 4.1**: The Flowchart of the system

## 4.3 Output of System

### 4.3.1 Sensor Output

The electrochemical sensor used in this project need at least +5V of voltage input to be implemented properly. Wheatstone bridge principle is used in this sensor to calculate the output voltage across load resistor. The output voltage of the sensor in normal condition when there is no toxic gas detected is around +3.5V. It will then increase rapidly when a toxic gas is detected. In this project, lighter which contain butane gas is used as the toxic gas. The output before and after toxic is detected is shown in Figure 4.2 and 4.3.

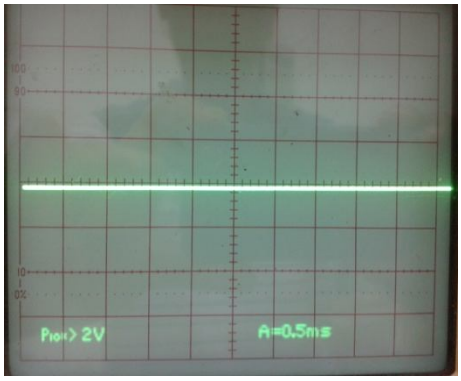


**Figure 4.2**: Sensor output before toxic detected

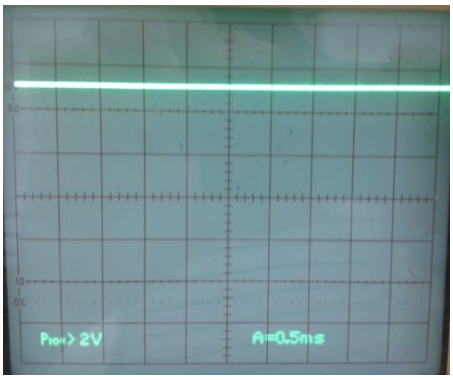


**Figure 4.3**: Sensor output after toxic detected

### 4.3.2 GSM Modem Output

When there is no toxic detected by the system, there is no data sent to the GSM modem by the PIC microcontroller as shown in Figure 4.4. When there is toxic detected, the PIC microcontroller will communicate with GSM modem by ordering the modem to send a SMS indicating the address of the factory that disposed the toxic waste. Figure 4.5 shows a pulse representing the SMS being sent by the GSM modem.

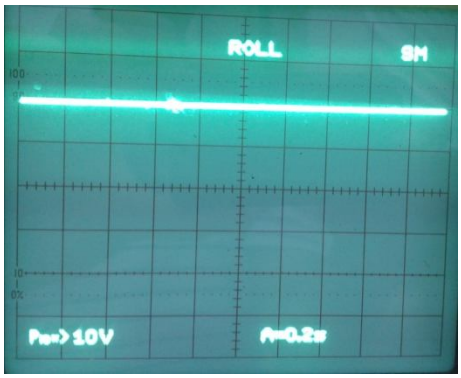


**Figure 4.4**: GSM Modem output before data is send

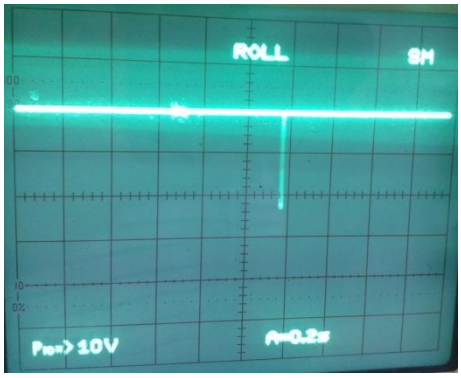


**Figure 4.5**: GSM Modem output when data is send

### 4.3.3 GUI Application Result

The SMS sent by the detection system will be received by the monitoring system which will be display on the GUI application of the system. The mobile phone connected to the computer will received the SMS being sent and the SMS will be transferred directly to the application to be displayed. The SMS will display the detection system phone number, date and time of the SMS being sent as well as the factory address. Figure 4.6 shows the SMS received by the GUI application at the monitoring system.

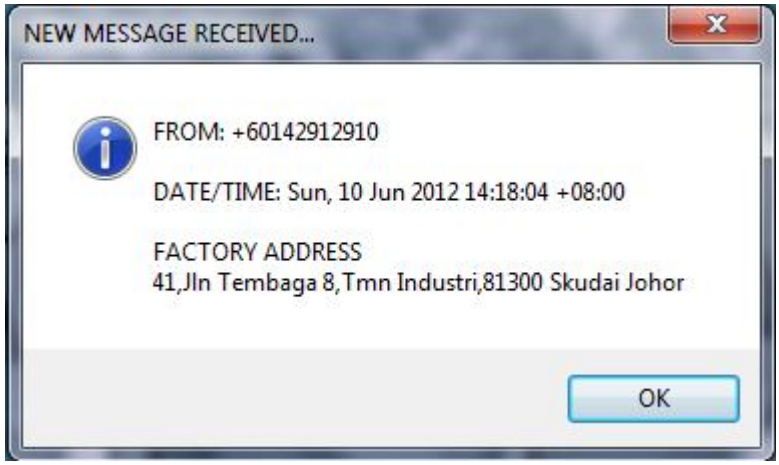


**Figure 4.6**: Message Box of GUI Application

## 4.4 Problems Encountered and Solution

There are several problems faced during the development of the project including the software and hardware. The main problem encountered when attempt to interface between the PIC microcontroller and the GSM modem failed. The GSM modem does not send any response to the PIC microcontroller despite data from the PIC accepted. This cause the sending of SMS when toxic gas detected failed to

occur. Another problem comes about when writing the program to create the GUI application for the system. There is a problem to display and organize the received SMS from the detection system into the application.

The former problem is solved by testing the UART to RS232 converter circuit. The circuit is connected between the PIC microcontroller and a computer to test whether there is data received or sent. After testing the converter circuit, it is found that the converter circuit has connection error. Pin 7 and pin 8 of DB9 component of the converter circuit is shorted when in fact it should never have. The mistake was corrected; afterward the PIC and GSM modem interface finally runs smoothly. The later problem then solved by studying and understanding more about ways to transfer the SMS received by the mobile phone to the GUI application for viewing.

Another problem that plagued in the early development of this project is when the mobile phone used as a receiver to receive the sent message at the monitoring location cannot be accessed to read the message which came from the detection system. Due to this, hyperterminal application is used to verify the problem. After a closer investigation, it is founded that all new model of Nokia mobile phones is not accessible to obtain or display all the messages received by the phone. Eventually the problem is solved by changing the Nokia phone model to another manufacturer model that provided access to its inbox message. All other problems are also solved to make sure the project to be successful.

# CHAPTER 5

# CONCLUSION

## 5.1 Conclusion

Year after year, toxic wastes generation rate in Malaysia experienced a significant increase in accordance with the increasing development of the industrial areas. With the current trends of rapid population growth and industrialisation, wastes and pollutants are released faster than the earth can absorb them, such that maintaining a sustainable environment is becoming a challenging task. [4] Therefore, the issue of illegal toxic waste disposal faced this day require a more efficient settlement. Continuous surveillance against these illegal activities requires a robust mobile system that has an immediate response with enough sensitivity as well as long lifespan.

From the studies and research that have been taken in the development of the project, it is concluded that the GSM wireless technology applied in the project can provide a fast and effective way for sending and receiving data for the system wherever the system is located. The project is replicating the normal way of communicating with the authorities such as those used by police and fire department before. The only different is the system automatically reports the case by SMS immediately after toxic waste detected without depending on the user.

With the increasing cost to be incurred by the industries to dispose their toxic waste in accordance to the law, most likely this illegal activity will be more prevalent if not contained. This project will assist the authorities to detect any attempt to dispose of toxic waste illegally by the industries with more fast and effective approach. This project also succeeded in fulfilling every criterion needed to ensure that every unlawful activity to dispose toxic waste by the industry can be traced.

## 5.2 Recommendation

To increase the capability of a product, continuous research and improvement is needed to ensure the products remain competitive. Some improvements can be made on this project to maximize its performance and overcome the limitations as well as providing greater benefits to users. The industrial illegal toxic waste via smart detection system can be enhanced by using GPS technology for its wireless communication. This GPS technology will ensure that the location of illegal disposal of toxic waste incident can be specified more accurate without requiring any use of SMS to find out the address of the industries. Improvements are also needed in the use of this project to allow only one system needed to detect illegal dumping of toxic waste activities for the area around without requiring the installation of many similar systems in one area.

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# APPENDICES

## APPENDIX A

TGS2600 User Manual

FIGARO

PRODUCT INFORMATION

### TGS 2600 - for the detection of Air Contaminants

**Features:**

* Low power consumption
* High sensitivity to gaseous air contaminants
* Long life and low cost
* Uses simple electrical circuit
* Small size

**Applications:**

* Air cleaners
* Ventilation control
* Air quality monitors

The sensing element is comprised of a metal oxide semiconductor layer formed on an alumina substrate of a sensing chip together with an integrated heater. In the presence of a detectable gas, the sensor's conductivity increases depending on the gas concentration in the air. A simple electrical circuit can convert the change in conductivity to an output signal which corresponds to the gas concentration.

The **TGS 2600** has high sensitivity to low concentrations of gaseous air contaminants such as hydrogen and carbon monoxide which exist in cigarette smoke. The sensor can detect hydrogen at a level of several ppm. Figaro also offers a microprocessor (FIC93619A) which contains special software for handling the sensor's signal for appliance control applications.

Due to miniaturization of the sensing chip, TGS 2600 requires a heater current of only 42mA and the device is housed in a standard TO-5 package.

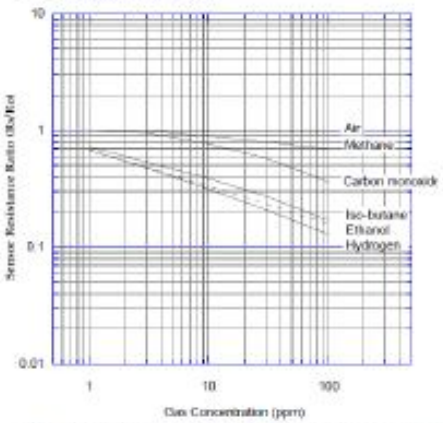
The figure below represents typical sensitivity characteristics, all data having been gathered at standard test conditions (see reverse side of this sheet). The Y-axis is indicated as *sensor resistance ratio* (Rs/Ro) which is defined as follows:

Rs = Sensor resistance in displayed gases at various concentrations
Ro = Sensor resistance in fresh air

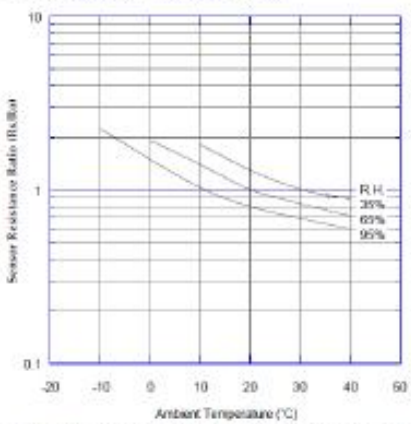
The figure below represents typical temperature and humidity dependency characteristics. Again, the Y-axis is indicated as *sensor resistance ratio* (Rs/Ro), defined as follows:

Rs = Sensor resistance in fresh air at various temperatures/humidities
Ro = Sensor resistance in fresh air at 20°C and 65% R.H.

Sensitivity Characteristics:



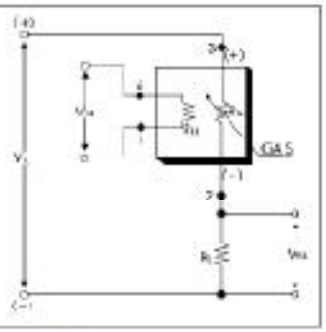

Temperature/Humidity Dependency:




IMPORTANT NOTE: OPERATING CONDITIONS IN WHICH FIGARO SENSORS ARE USED WILL VARY WITH EACH CUSTOMER'S SPECIFIC APPLICATIONS. FIGARO STRONGLY RECOMMENDS CONSULTING OUR TECHNICAL STAFF BEFORE DEPLOYING FIGARO SENSORS IN YOUR APPLICATION AND, IN PARTICULAR, WHEN CUSTOMER'S TARGET GASES ARE NOT LISTED HEREIN. FIGARO CANNOT ASSUME ANY RESPONSIBILITY FOR ANY USE OF ITS SENSORS IN A PRODUCT OR APPLICATION FOR WHICH SENSOR HAS NOT BEEN SPECIFICALLY TESTED BY FIGARO.

### Basic Measuring Circuit:

The sensor requires two voltage inputs: heater voltage ($V_H$) and circuit voltage ($V_C$). The heater voltage ($V_H$) is applied to the integrated heater in order to maintain the sensing element at a specific temperature which is optimal for sensing. Circuit voltage ($V_C$) is applied to allow measurement of voltage ($V_{out}$) across a load resistor ($R_L$) which is connected in series with the sensor. DC voltage is required for the circuit voltage since the sensor has a polarity. A common power supply circuit can be used for both $V_C$ and $V_H$ to fulfill the sensor's electrical requirements. The value of the load resistor ($R_L$) should be chosen to optimize the alarm threshold value/keeping power consumption ($P_S$) of the semiconductor below a limit of 15mW. Power consumption ($P_S$) will be highest when the value of $R_S$ is equal to $R_L$ on exposure to gas.




## Specifications:

| Model number | | | TGS 2600 | |
|---|---|---|---|---|
| Sensing element type | | | D1 | |
| Standard package | | | TO-5 metal can | |
| Target gases | | | Air contaminants | |
| Typical detection range | | | 1 ~ 10 ppm of $H_2$ | |
| Standard circuit conditions | Heater voltage | $V_H$ | 5.0±0.2V DC/AC | |
| | Circuit voltage | $V_C$ | 5.0±0.2V DC | $P_S \leq 15mW$ |
| | Load resistance | $R_L$ | Variable | $P_S \leq 15mW$ |
| Electrical characteristics under standard test conditions | Heater resistance | $R_H$ | approx. 60Ω at room temp. (typical) | |
| | Heater current | $I_H$ | 42±4mA | |
| | Heater power consumption | $P_H$ | 210mW | $V_H$=5.0V DC |
| | Sensor resistance | $R_S$ | 10k~60kΩ in air | |
| | Sensitivity (change ratio of $R_S$) | | 0.3~0.6 | $\frac{R_S\ (1ppm\ of\ H_2)}{R_S\ (air)}$ |
| Standard test conditions | Test gas conditions | | normal air at 20±2°C, 65±5%RH | |
| | Circuit conditions | | $V_C$ = 5.0±0.01V DC<br>$V_H$ = 5.0±0.05V DC | |
| | Conditioning period before test | | 7 days | |

The value of power consumption ($P_S$) can be calculated by utilizing the following formula:

$$P_S = \frac{(V_H - V_{out})^2}{R_S}$$

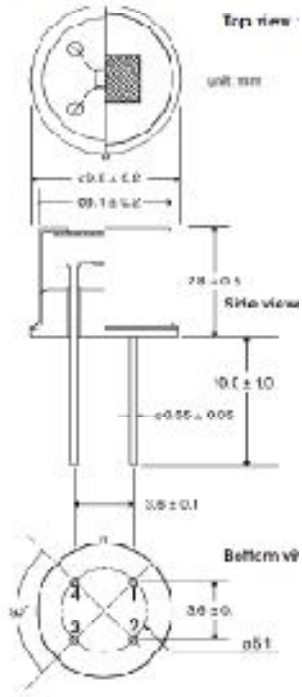
Sensor resistance ($R_S$) is calculated with a measured value of $V_{out}$ by using the following formula:

$$R_S = \frac{V_C \times R_L}{V_{out}} - R_L$$

For information on warranty, please refer to Standard Terms and Conditions of Sale of Figaro USA Inc.

REV: 09/01

## Structure and Dimensions:




**Pin connection:**
1 : Heater
2 : Sensor electrode (-)
3 : Sensor electrode (+)
4 : Heater

**FIGARO USA, INC.**
3703 West Lake Ave. Suite 203
Glenview, Illinois 60025
Phone: (847)-832-1701
Fax: (847)-832-1705
e-mail: figarousa@figarosensor.com

**APPENDIX B**

**PIC16F877A Source Code**

```
#define SW1 PORTB.F0
#define SW2 PORTB.F1

//output
//LED
#define LED1 PORTB.F6
#define LED2 PORTB.F7

//LCD definition
sbit LCD_RS at RB4_bit;
sbit LCD_EN at RB5_bit;
sbit LCD_D4 at RD4_bit;
sbit LCD_D5 at RD5_bit;
sbit LCD_D6 at RD6_bit;
sbit LCD_D7 at RD7_bit;

sbit LCD_RS_Direction at TRISB4_bit;
sbit LCD_EN_Direction at TRISB5_bit;
sbit LCD_D4_Direction at TRISD4_bit;
sbit LCD_D5_Direction at TRISD5_bit;
sbit LCD_D6_Direction at TRISD6_bit;
sbit LCD_D7_Direction at TRISD7_bit;
//end port definition


//variable declaration
char txt[14];
char ptxt[14];
unsigned char enter = 0x0D;
unsigned long value, percent;
```

```
//end variable declaration


//function prototype declaration

void initialization(void);
void sms(char num[],char txt[]);
//end function prototype declaration

//starting main program
void main()
{unsigned char count=1;
initialization();


while(1)
{
count=0;
value=ADC_Read(0);
percent=((value*100)/1023);
IntToStr(percent,ptxt);
Lcd_Out(1,1,"");
Lcd_Out(2,4,ptxt);

if ((SW2==0)||(percent>85))
{

//delay_ms(2000);

while(SW1==1){
Lcd_Out(1,1,"   Report Sent   ");
Lcd_Out(2,1,"Press SW1-Exit");
if(count<1)
  {
```

```
 sms("0175553152","41,Jln Tembaga 8,Tmn Industri,81300 Skudai Johor");
 count=count+1;
 }
}
Lcd_Cmd(_LCD_CLEAR);
}

//else{}

}
}


//initialization function
void initialization(void)
{
TRISA=0b00000001;       //tris port 1=input 0=output   declare by
TRIS'port'=0b'port7-port0'
TRISB=0b00000011;
TRISC=0b10000000;
ADC_Init();
ADCON1=0b00001110;


Lcd_Init();                          //initialization LCD
UART1_Init(115200);

PORTD.F3=PORTD.F2=PORTD.F1=PORTD.F0=0;
LED1=LED2=0;

Lcd_Cmd(_LCD_CLEAR);       //clearing LCD
Lcd_Cmd(_LCD_CURSOR_OFF);
```

```
UART1_Write_Text("AT+CMGF=1");        //initialize gsm to send sms by words
while(UART1_Tx_Idle() == 0);
 UART1_Write(enter);
while(UART1_Tx_Idle() == 0);
delay_ms(150);
}

void sms(char num[],char txt[]){

      UART1_Write_Text("AT+CMGS=");         // send SMS
         UART1_Write(0x22);                  //"
         UART1_Write_Text(num);       // phone number to be sent
         UART1_Write(0x22);
         UART1_Write(enter);
         delay_ms(1000);                        // wait for gsm respons
         UART1_Write_Text(txt);  // text to be sent
         UART1_Write(0x1A);                     // ctrl+z
         Lcd_Cmd(_LCD_CLEAR);
         Lcd_Out(1,1," Sending SMS To ");
         Lcd_Out(2,4,num);
         delay_ms(3000);
         Lcd_Cmd(_LCD_CLEAR);
}
```

**APPENDIX C**

**Microsoft Visual Basic 2008 source code**

```
Public Class frmMain
    Private WithEvents objSMS As New mCore.SMS
    Private strMyAppName As String = "Connection Status"
    Private blnFormLoaded As Boolean = False

    Private Sub frmMain_FormClosed(ByVal sender As Object, ByVal e As
System.Windows.Forms.FormClosedEventArgs) Handles Me.FormClosed
        objSMS.Dispose()
        objSMS = Nothing
    End Sub

    Private Sub frmMain_Load(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles MyBase.Load
        Dim i As Integer

        '-----------------------------------
        'Initialize COM Port DropDown List
        '-----------------------------------
        cboPort.Items.Add("Select Port")
        For i = 1 To 50
            cboPort.Items.Add("COM" & i.ToString)
        Next
        cboPort.SelectedIndex = 0

        '-----------------------------------
        'Initialize BaudRate DropDown List
        '-----------------------------------
        With cboBaudRate
            .Items.Add("110")
            .Items.Add("300")
```

```
            .Items.Add("1200")
            .Items.Add("2400")
            .Items.Add("4800")
            .Items.Add("9600")
            .Items.Add("14400")
            .Items.Add("19200")
            .Items.Add("38400")
            .Items.Add("57600")
            .Items.Add("115200")

        End With
        cboBaudRate.SelectedIndex =
cboBaudRate.FindString(CType(objSMS.BaudRate, Integer).ToString)


        '-------------------------------------------------
        'Initialize new incoming message indication setting
        '-------------------------------------------------
        chkNewMsgIndication.Checked = True

        chkNewMsgIndication.Enabled = False


    End Sub

    Private Sub cmdConnect_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles cmdConnect.Click


        Try
            If cboPort.SelectedIndex = 0 Then
                MsgBox("Select a serial port", MsgBoxStyle.Critical, strMyAppName)
                Exit Sub
            End If
```

```
            cmdConnect.Text = "Please Wait..."
            cmdConnect.Enabled = False
            cmdDisconnect.Enabled = False

            SetCommParameters()

            If objSMS.Connect() Then
                cmdConnect.Enabled = False
                cmdDisconnect.Enabled = True




                objSMS.MessageMemory = mCore.MessageMemory.SM


                MsgBox("Connection successful", MsgBoxStyle.Information,
strMyAppName)

            Else
                MsgBox("Connection error", MsgBoxStyle.Critical, strMyAppName)

                cmdConnect.Enabled = True
                cmdDisconnect.Enabled = False
            End If


        Catch ex As mCore.GeneralException
            MsgBox(ex.Message, MsgBoxStyle.Critical, strMyAppName)
            Exit Try

        Catch ex As Exception
            MsgBox(ex.Message, MsgBoxStyle.Critical, strMyAppName)
```

```
            Exit Try

        End Try

        Try
            cmdConnect.Text = "Connect"
            If objSMS.IsConnected Then
                cmdConnect.Enabled = False
                cmdDisconnect.Enabled = True
            Else
                cmdConnect.Enabled = True
                cmdDisconnect.Enabled = False
            End If
        Catch ex As Exception

        End Try

    End Sub

    Private Sub cmdDisconnect_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles cmdDisconnect.Click


        cmdDisconnect.Text = "Please Wait..."
        cmdDisconnect.Enabled = False
        cmdConnect.Enabled = False

        Try
            objSMS.Disconnect()
            cmdConnect.Enabled = True
            cmdDisconnect.Enabled = False

        Catch ex As mCore.GeneralException
            MsgBox(ex.Message, MsgBoxStyle.Critical, strMyAppName)
```

```
            Exit Try

        Catch ex As Exception
            MsgBox(ex.Message, MsgBoxStyle.Critical, strMyAppName)
            Exit Try
        End Try

        cmdDisconnect.Text = "Disconnect"
    End Sub

    Private Sub objSMS_NewMessageReceived(ByVal sender As Object, ByVal e As
mCore.NewMessageReceivedEventArgs) Handles objSMS.NewMessageReceived
        'New Message Indication Event
        'Display the new message

My.Computer.Audio.Play(My.Resources.Siren_Wav____MP3_Sounds,AudioPlayM
ode.Background)
        MsgBox("FROM: " & e.Phone & vbCrLf & vbCrLf & "DATE/TIME: " &
e.TimeStampRFC & vbCrLf & vbCrLf & "FACTORY ADDRESS" & vbCrLf &
e.TextMessage, MsgBoxStyle.Information, "NEW MESSAGE RECEIVED...")

        Control.CheckForIllegalCrossThreadCalls = False

        Control.CheckForIllegalCrossThreadCalls = True

    End Sub

    Public Sub SetCommParameters()
        'Set communication parameters
        'check if port is already connected

        Try
            If Not objSMS.IsConnected And cboPort.SelectedIndex > 0 Then
                objSMS.Port = cboPort.Text
```

```
            objSMS.BaudRate = CType(CInt(cboBaudRate.Text), mCore.BaudRate)
            objSMS.DataBits = mCore.DataBits.Eight
            objSMS.Parity = mCore.Parity.None
            objSMS.StopBits = mCore.StopBits.One
            objSMS.FlowControl = mCore.FlowControl.RTS_CTS
            objSMS.PIN = txtPIN.Text

        End If

    Catch ex As mCore.GeneralException
        MsgBox(ex.Message, MsgBoxStyle.Critical, strMyAppName)

    End Try
End Sub

Private Sub chkNewMsgIndication_CheckedChanged(ByVal sender As
System.Object, ByVal e As System.EventArgs) Handles
chkNewMsgIndication.CheckedChanged

    Try
        chkNewMsgIndication.Enabled = False

        SetCommParameters()

        objSMS.NewMessageIndication = chkNewMsgIndication.Checked

    Catch ex As mCore.GeneralException

        chkNewMsgIndication.Checked = objSMS.NewMessageIndication
        Exit Try
```

```
        Catch ex As Exception
            Exit Try

        End Try

        chkNewMsgIndication.Enabled = True

    End Sub

End Class
```